

D E C L A R A T I O N

In the matter of U.S. Patent
Application Ser. No. 10/568,628
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[Document Name] CLAIMS

[Claim 1]

A double-stranded RNA molecule capable of suppressing the expression of a target gene in a cell by RNAi, which is designed such 5 that one or more nucleotides in order from the 3'-end of the sense strand of double-stranded part in said RNA molecule are not complementary to the antisense strand,

wherein the sense strand of the double-stranded part has adequate number of nucleotides which are complementary to the 10 antisense strand for enabling the hybridization of both strands in said cell.

[Claim 2]

The double-stranded RNA molecule according to claim 1, wherein the number of the nucleotides which are not complementary 15 to the antisense strand in order from the 3'-end of the sense strand of the double-stranded part is 1 to 4.

[Claim 3]

The double-stranded RNA molecule according to claim 1, wherein the number of the nucleotides which are not complementary 20 to the antisense strand in order from the 3'-end of the sense strand of the double-stranded part is 2.

[Claim 4]

The double-stranded RNA molecule according to claim 1, which is designed such that one additional nucleotide located at position 11- 25 13 from the 3'-end of the sense strand of the double-stranded part is not complementary to the antisense strand.

[Claim 5]

The double-stranded RNA molecule according to claim 4, which is designed such that a nucleotide located at position 12 from the 3'- 30 end of the sense strand of the double-stranded part is not complementary to the antisense strand.

[Claim 6]

The double-stranded RNA molecule according to claim 1, which is designed such that one additional nucleotide located at nucleotide 35 position 1-3 in 5'- or 3'-direction from a site on the sense strand of the double-stranded part is not complementary to the antisense

strand, the site corresponding to the cleavage site of the target gene transcription product by RISC.

[Claim 7]

5 The double-stranded RNA molecule according to claim 1, which is designed such that one additional nucleotide located at nucleotide position 1-3 in 5'-direction from the nucleotide in the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense strand has an odd number of nucleotides, and that one additional nucleotide 10 located at nucleotide position 1-3 in 5'-direction from the nucleotide at the 3'-side of the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense strand has an even number of nucleotides.

[Claim 8]

15 The double-stranded RNA molecule according to claim 1, which is designed such that one additional nucleotide located at nucleotide position 2 in 5'-direction from the nucleotide in the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense strand 20 has an odd number of nucleotides, and that one additional nucleotide located at nucleotide position 2 in 5'-direction from the nucleotide at the 3'-side of the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense strand has an even number of nucleotides.

25 [Claim 9]

The double-stranded RNA molecule according to claim 1, which does not induce double-stranded RNA-dependent protein kinase or 2',5'-oligoadenylate synthetase in a mammalian cell.

[Claim 10]

30 The double-stranded RNA molecule according to claim 9, which has a strand length of 29 or less nucleotides.

[Claim 11]

35 A double-stranded RNA molecule capable of suppressing the expression of a target gene in a cell by RNAi, which is designed such that one or more nucleotides in order from the 5'-end of the sense strand of double-stranded part in said RNA molecule are not

complementary to the antisense strand,

wherein the sense strand of the double-stranded part has adequate number of nucleotides which are complementary to the antisense strand for enabling the hybridization of both strands in said

5 cell.

[Claim 12]

The double-stranded RNA molecule according to claim 11, wherein the number of the nucleotides which are not complementary to the antisense strand in order from the 5'-end of the sense strand of
10 the double-stranded part is 1 to 4.

[Claim 13]

The double-stranded RNA molecule according to claim 11, wherein the number of the nucleotides which are not complementary to the antisense strand in order from the 5'-end of the sense strand of
15 the double-stranded part is 2.

[Claim 14]

The double-stranded RNA molecule according to claim 11, which is designed such that one or more additional nucleotides in order from the 3'-end of the sense strand of the double-stranded part
20 are not complementary to the antisense strand.

[Claim 15]

The double-stranded RNA molecule according to claim 14, wherein the number of the nucleotides which are not complementary to the antisense strand in order from the 3'-end of the sense strand of
25 the double-stranded part is 1 to 4.

[Claim 16]

The double-stranded RNA molecule according to claim 14, wherein the number of the nucleotides which are not complementary to the antisense strand in order from the 3'-end of the sense strand of
30 the double-stranded part is 2.

[Claim 17]

The double-stranded RNA molecule according to claim 11, which is designed such that one additional nucleotide located at position 11-13 from the 3'-end of the sense strand of the double-
35 stranded part is not complementary to the antisense strand.

[Claim 18]

The double-stranded RNA molecule according to claim 17, which is designed such that a nucleotide located at position 12 from the 3'-end of the sense strand of the double-stranded part is not complementary to the antisense strand.

5 [Claim 19]

The double-stranded RNA molecule according to claim 11, which is designed such that one additional nucleotide located at nucleotide position 1-3 in 5'- or 3'-direction from a site on the sense strand of the double-stranded part is not complementary to the 10 antisense strand, the site corresponding to the cleavage site of the target gene transcription product by RISC.

[Claim 20]

The double-stranded RNA molecule according to claim 11, which is designed such that one additional nucleotide located at 15 nucleotide position 1-3 in 5'-direction from the nucleotide in the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense strand has an odd number of nucleotides, and that one additional nucleotide located at nucleotide position 1-3 in 5'- 20 direction from the nucleotide at the 3'-side of the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense strand has an even number of nucleotides.

[Claim 21]

25 The double-stranded RNA molecule according to claim 11, which is designed such that one additional nucleotide located at nucleotide position 2 in 5'-direction from the nucleotide in the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense 30 strand has an odd number of nucleotides, and that one additional nucleotide located at nucleotide position 2 in 5'-direction from the nucleotide at the 3'-side of the center of the sense strand of the double-stranded part is not complementary to the antisense strand when the double-stranded part of the sense strand has an even 35 number of nucleotides.

[Claim 22]

The double-stranded RNA molecule according to claim 11, which does not induce double-stranded RNA-dependent protein kinase or 2',5'-oligoadenylate synthetase in a mammalian cell.

[Claim 23]

5 The double-stranded RNA molecule according to claim 22, which has a strand length of 29 or less nucleotides.

[Claim 24]

10 A method for suppressing the expression of a target gene in a cell, comprising a step of introducing the double-stranded RNA molecule according to any one of claims 1-23 into the cell.

[Claim 25]

The method according to claim 24, wherein the cell is a mammalian cell.

[Claim 26]

15 A vector comprising both of a DNA encoding the sense strand of the double-stranded RNA molecule according to any one of claims 1-23 and a DNA encoding the antisense strand of said RNA molecule.

[Claim 27]

20 A method for suppressing the expression of a target gene in a cell, comprising a step of introducing a combination of a vector containing a DNA encoding the sense strand of the double-stranded RNA molecule according to any one of claims 1-23 and a vector containing a DNA encoding the antisense strand of said RNA molecule, or a vector according to claim 26, into the cell.

25 [Claim 28]

The method according to claim 27, wherein the cell is a mammalian cell.

[Document Name] SPECIFICATION

[Title of Invention] IMPROVED siRNA MOLECULE AND METHOD OF SUPPRESSING GENE EXPRESSION WITH THE USE OF THE SAME

[BACKGROUND OF THE INVENTION]

5 [0001]

Field of the Invention

The present invention relates to gene silencing by the RNAi phenomenon, and more specifically to improved siRNAs and a method for suppressing the expression of a target gene using this 10 phenomenon.

[0002]

Background Art

RNAi (RNA interference) is a mechanism of a sequence-specific posttranscriptional gene suppression triggered by double-stranded 15 RNAs (dsRNAs). This phenomenon has been found in various kinds of species including flies, insects, protozoa, vertebrates, and higher plants. A majority of studies on the molecular mechanism underlying RNAi activity has been conducted using *Drosophila* and *Caenorhabditis elegans* and demonstrated that RNA fragments of 21-25 nucleotides, 20 referred to as siRNAs (short interfering RNAs) are essential sequence-specific mediators of RNAi (Non-patent document 1: Hammond, S.M. et al., *Nature* 404, 293-296, 2000; Non-patent document 2: Parrish, S. et al., *Mol. Cell.* 6, 1077-1087, 2000; Non-patent document 3: Zamore, P.D. et al., *Cell* 101, 25-33, 2000) and that siRNAs are 25 generated from long double-stranded RNAs by digestion with an RNase III-like nuclease, Dicer (Non-patent document 4: Brenstein, E. et al., *Nature* 409, 363-366, 2001; Non-patent document 5: Elbashir, S.M. et al., *Genes Dev.* 15, 188-200, 2001).

[0003]

30 In mammals, it was initially thought that RNAi occurs only in oocytes and preimplantation embryos. Mammalian cells, in general, possess a rapid and non-specific RNA degradation pathway involving the sequence-non-specific RNase, RNase L, and a rapid translation inhibition pathway involving the interferon-inducible, dsRNA-activated 35 protein kinase (PKR), both of which can be activated by double-stranded RNAs of 30 nucleotides or more. Thus, the abovementioned

responses to double-stranded RNAs of 30 nucleotides or more may mask the sequence-specific RNAi activity in mammalian cells except for undifferentiated cells as well as differentiated cells that lack PKR. Recently, it has been reported that synthetic 21-nucleotide siRNA duplexes can specifically inhibit the expression of endogenous genes in cultured mammalian cells (Non-patent document 6: Elbashir, S.M. et al., *Nature* 411, 494-498, 2001).

[0004]

The principle of the suppression of gene expression by RNAi is thought to be as follows. First, when introduced in a cell, siRNA is incorporated into a multi-protein complex to form an RISC (RNA-induced silencing complex). Then, this RISC bonds to mRNA from a target gene and its nuclelease activity cleaves the site to which siRNA is attached in the mRNA. As a result, the expression of the protein by the target gene is inhibited.

[0005]

In recent years, a method of using the RNAi phenomenon by the introduction of a synthetic siRNA into a cell has drawn attention and been utilized as a method for the suppression of gene expression. Further, the relation of the structure of siRNA and its effect on the suppression of gene expression has also been studied.

[0006]

For example, in a report by Hohjoh H. (Non-patent document 7: Hohjoh H., *FEBS Letters* 521, 195-199, 2002), various types of synthetic oligonucleotide duplexes designed for the Photinus luciferase gene were tested on their effect on suppressing the expression of said gene in mammalian cells. This report describes that 2-ribonucleotide overhangs at each 3'-end of sense and antisense strands are *inter alia* preferable, that the structure of antisense strands is important, and that the resultant effect on suppression of gene expression varies dependent on target sequences of the gene of interest.

[0007]

In a report by Hamada M. et al (Non-patent document 8: Hamada M. et al., *Antisense Nucleic Acid Drug Dev.* 12, 301-309, 2002), the effect on suppressing the expression of a target gene is studied using siRNAs into which one or more discontinued mismatches

with a target sequence are introduced at sites other than each 3'-end of sense and/or antisense strands. This report describes that the effect on suppressing the gene expression is reduced by the mismatches with the target sequence in the antisense strand while 5 the mismatches in the sense strand have no effect on suppressing the gene expression.

[0008]

[Non-patent document 1] Hammond, S.M. et al., *Nature* 404, 293-296, 2000

10 [Non-patent document 2]. Parrish, S. et al., *Mol. Cell.* 6, 1077-1087, 2000

[Non-patent document 3] Zamore, P.D. et al., *Cell* 101, 25-33, 2000

15 [Non-patent document 4] Brenstein, E. et al., *Nature* 409, 363-366, 2001

[Non-patent document 5] Elbashir, S.M. et al., *Genes Dev.* 15, 188-200, 2001

[Non-patent document 6] Elbashir, S.M. et al., *Nature* 411, 494-498, 2001

20 [Non-patent document 7] Hohjoh H., *FEBS Letters* 521, 195-199, 2002

[Non-patent document 8] Hamada M. et al., *Antisense Nucleic Acid Drug Dev.* 12, 301-309, 2002

[SUMMARY OF THE INVENTION]

25 [0009]

The present inventor has found that in siRNA, the effect of siRNA on suppressing the gene expression is enhanced by introducing mismatches with the antisense strand in several nucleotides at the 3'-end of the sense strand in the double-stranded part. Further, the 30 present inventor has found that in siRNA, the effect of siRNA on suppressing the gene expression is reduced by introducing mismatches with the antisense strand in several nucleotides at the 5'-end of the sense strand in the double-stranded part. The present invention is based on these findings.

35 [0010]

Accordingly, an object of the present invention is to provide a

double-stranded RNA molecule which is an siRNA so improved to control its effect on suppressing the gene expression, and a method for suppressing the gene expression using this RNA molecule.

[0011]

5 In a first aspect of the present invention, there is provided a double-stranded RNA molecule capable of suppressing the expression of a target gene in a cell by RNAi, which is designed such that one or more nucleotides in order from the 3'-end of the sense strand of double-stranded part in said RNA molecule are not complementary to 10 the antisense strand, wherein the sense strand of the double-stranded part has adequate number of nucleotides which are complementary to the antisense strand for enabling the hybridization of both strands in said cell.

[0012]

15 In a second aspect of the present invention, there is provided a double-stranded RNA molecule capable of suppressing the expression of a target gene in a cell by RNAi, which is designed such that one or more nucleotides in order from the 5'-end of the sense strand of double-stranded part in said RNA molecule are not complementary to 20 the antisense strand, wherein the sense strand of the double-stranded part has adequate number of nucleotides which are complementary to the antisense strand for enabling the hybridization of both strands in said cell.

[0013]

25 Further, a method for suppressing the gene expression of the present invention is a method for suppressing the expression of a target gene in a cell, comprising a step of introducing a double-stranded RNA molecule of the present invention into the cell.

[0014]

30 According the present invention, it becomes possible to control the efficiency of the suppression of the expression in the method for the suppression of the expression of the target gene using an RNAi phenomenon.

[DETAILED DESCRIPTION OF THE INVENTION]

35 [0015]

The term "double-stranded RNA" as used herein means an RNA

molecule which is obtained by overall or partial hybridization of two single-stranded RNA molecules. The number of nucleotides in each of the single-stranded RNAs can be different one another. Further, either one or both of the nucleotide strands in the double-stranded RNA may 5 contain a single-stranded part (overhang).

[0016]

The term "double-stranded part" as used herein means a part where in a double-stranded RNA, nucleotides of both strands are paired, namely a part excluding a single-stranded part in the double-10 stranded RNA.

[0017]

The term "sense strand" as used herein means a nucleotide strand that has a sequence homologous to a coding strand of a gene, and the term "antisense strand" means a nucleotide strand that has a 15 sequence complementary to the coding strand of the gene.

[0018]

The term "complementary" as used herein means that two nucleotides can be paired under hybridization conditions, for example, relations between adenine (A) and thymine (T) or uracil (U), and 20 between cytosine (C) and guanine (G).

[0019]

A double-stranded RNA molecule capable of suppressing the expression of a target gene in a cell by RNAi can be designed easily by those skilled in the art based on the existing knowledge on RNAi. 25 In general, first, a region specific to the target gene is selected and a ribonucleotide strand which is specifically hybridizable with this region in a cell is to be the antisense strand of the abovementioned double-stranded RNA molecule. The term "specific region" as used herein means a region having a sequence that cannot be found in other nucleic 30 acid molecules in the cell in which the suppression of the expression of the target gene is to be carried out. Further, the term "specifically hybridizable" means that the antisense strand does not hybridize with any nucleic acid molecules other than the target gene and its transcription products in the cell in which the suppression of the 35 expression of the target gene is to be carried out. The abovementioned antisense strand is to contain a sequence

corresponding to the abovementioned specific region; however, it may not necessarily have a sequence completely complementary to the abovementioned region and may contain noncomplementary nucleotides as long as it is specifically hybridizable with the specific 5 region. However, the abovementioned antisense strand is preferably to have a sequence completely complementary to the abovementioned region. The sense strand of the double-stranded RNA molecule is to contain a sequence completely complementary to the antisense strand.

10 [0020]

The abovementioned specific region to be selected in the target gene is selected preferably only from exons in the target gene. Further, it is generally believed to be preferable to select the abovementioned specific region from portions excluding 5'- and 3'-nontranslated 15 regions (UTRs) and the proximity to the translation initiation codon; for example, in a sequence containing both exons and introns, it is a region preferably 50 or more nucleotides distant from the 3'-end of the translation initiation codon, a region more preferably 75 or more nucleotides distant, most preferably 100 or more nucleotides distant, 20 from the 3'-end of the translation initiation codon. The length of the abovementioned specific region is not particularly limited but is preferably 15 or more nucleotides long, more preferably 17 or more nucleotides long, still more preferably 19 or more nucleotides long, further more preferably 19-23 nucleotides long, and most preferably 25 19-21 nucleotides long.

[0021]

The antisense strand of the abovementioned RNA molecule may have a single-stranded part (overhang) at the 3'-end of the double-stranded part paired with the nucleotides of the sense strand. 30 The nucleotide sequence of this single-stranded part can be either a sequence related or unrelated to the target gene and its length is not particularly limited but is preferably a sequence of two or more nucleotides and more preferably two uracil residues (UU). The sense strand can also have a similar overhang.

35 [0022]

The double-stranded RNA molecule according to a first aspect

of the present invention is designed such that, in the abovementioned double-stranded RNA molecule, one or more nucleotides in order from the 3'-end of the sense strand of double-stranded part in said RNA molecule are not complementary to the antisense strand. Namely, the 5 sense strand of the double-stranded RNA molecule according to the first aspect possesses one or more mismatches with the antisense strand in order from the 3'-end of double-stranded part of the sense strand. Thereby the effect on the suppression of the expression of the target gene is enhanced. However, these sense strand and antisense 10 strand have to be maintained as a double-stranded structure in the cell and thus the number of the mismatched nucleotides is restricted by the number of nucleotides which are complementary to the antisense strand necessary to maintain the double-stranded structure. Therefore, in the double-stranded RNA molecule according to the first 15 aspect of the present invention, the sense strand of the double-stranded part has adequate number of nucleotides which are complementary to the antisense strand for enabling the hybridization of both strands in the cell.

[0023]

20 Whether or not two ribonucleotide sequences hybridize in a cell can be examined by those skilled in the art. For example, hybridization conditions in a cell of interest can be reproduced in vitro and the two ribonucleotide strands can be added thereto to examine whether or not they hybridize.

25 [0024]

In a preferred embodiment for the double-stranded RNA molecule according to the first aspect of the present invention, the number of the nucleotides which are not complementary to the antisense strand in order from the 3'-end of the sense strand of the 30 double-stranded part is preferably 1 to 4, more preferably 2.

[0025]

In order to efficiently suppress the expression of the target gene in the cell, in addition to the abovementioned mismatch at the 3'-end of the sense strand, it is advantageous to introduce a 35 mismatch in one nucleotide located at position 11-13 from its 3'-end. Therefore, in a preferred embodiment of the present invention, the

double-stranded RNA molecule according to the first aspect of the present invention is designed such that one additional nucleotide located at position 11-13, more preferably at position 12, from the 3'-end of the sense strand of the double-stranded part is not 5 complementary to the antisense strand.

[0026]

It has been confirmed by the experimental data using a double-stranded RNA molecule in which mismatches are introduced in two nucleotides at the 3'-end and in one nucleotide at position 12 10 from the 3'-end in a 19-20 nucleotide long sense strand, that the double-stranded RNA molecule having a mismatch in one nucleotide located at position 11-13 from the 3'-end of the sense strand of the double-stranded part is advantageous in enhancing the effect on suppressing the gene expression. Further, the site of this mismatch is 15 close to the cleavage site of the target gene transcription product by RISC. Therefore, in the double-stranded RNA molecule according to the first aspect of the present invention, in addition to the mismatches at the 3'-end of the double-stranded part of the sense strand, a mismatch may be introduced in one nucleotide located at nucleotide 20 position 1-3 in 5'- or 3'-direction from a site on the sense strand of the double-stranded part, the site corresponding to the cleavage site of the target gene transcription product by RISC. The cleavage site of the target gene transcription product by RISC can be determined by 25 those skilled in the art according to the sequence in the specific region of the target gene contained in the double-stranded RNA molecule; however, it is typically in the central part of the sequence of the abovementioned specific region.

[0027]

In a preferred embodiment for the double-stranded RNA 30 molecule according to the first aspect of the present invention, in addition to the mismatches at the 3'-end of the double-stranded part of the sense strand, a mismatch is introduced in one nucleotide located at nucleotide position 1-3, preferably at nucleotide position 2, in 5'-direction from the nucleotide in the center when the double-stranded part of the sense strand has an odd number of nucleotides, 35 while it is introduced in one nucleotide located at nucleotide position

1-3, preferably at nucleotide position 2, in 5'-direction from the nucleotide at the 3'-side of the center when the double-stranded part of the sense strand has an even number of nucleotides.

[0028]

5 The double-stranded RNA molecule according to a second aspect of the present invention is designed such that, in the double-stranded RNA molecule capable of suppressing the expression of the target gene in the cell by RNAi, one or more nucleotides in order from the 5'-end of the sense strand of double-stranded part in said RNA
10 molecule are not complementary to the antisense strand. Namely, the sense strand of the double-stranded RNA molecule according to the second aspect possesses one or more mismatches with the antisense strand in order from the 5'-end of double-stranded part of the sense strand. Thereby the effect on the suppression of the expression of the
15 target gene is reduced. However, these sense strand and antisense strand have to be maintained as a double-stranded structure in the cell and thus the number of the mismatched nucleotides is restricted by the number of nucleotides which are complementary to the antisense strand necessary to maintain the double-stranded structure.
20 Therefore, in the double-stranded RNA molecule according to the second aspect of the present invention, the sense strand of the double-stranded part has adequate number of nucleotides which are complementary to the antisense strand for enabling the hybridization of both strands in the cell.

25 [0029]

In a preferred embodiment for the double-stranded RNA molecule according to the second aspect of the present invention, the number of the nucleotides which are not complementary to the antisense strand in order from the 5'-end of the sense strand of the double-stranded part is preferably 1 to 4, more preferably 2.

[0030]

The double-stranded RNA molecule according to the second aspect of the present invention can further contain a part or all of the mismatches in the sense strand as described above with regard to the double-stranded RNA molecule according to the first aspect. Thereby the effect on the suppression of the expression of the target gene can

be finely controlled.

[0031]

It is known that when a long double-stranded RNA molecule is introduced into a mammalian cell, double-stranded RNA-dependent protein kinase and 2',5'-oligoadenylate synthetase are induced, which may results in cell death. Therefore, the double-stranded RNA molecule of the present invention preferably does not induce the double-stranded RNA-dependent protein kinase or 2',5'-oligoadenylate synthetase in mammalian cells. The strand length of the double-stranded RNA molecule which satisfies this condition is easily understood by those skilled in the art. It is known that the abovementioned cell death is generally caused by 30 or more nucleotide-long double-stranded RNA molecules; therefore, the double-stranded RNA molecule of the present invention has a strand length of preferably 29 or less nucleotides, more preferably 25 or less nucleotides. The term "strand length" as used herein means not only a nucleotide length of the double-stranded part of the double-stranded RNA molecule but also includes that of the single-stranded part.

20 [0032]

The double-stranded RNA molecule of the present invention can suppress the expression of a target gene in a cell. Thus, according to the present invention, there is provided a method for suppressing the expression of a target gene in a cell, comprising a step of introducing the double-stranded RNA molecule of the present invention into the cell.

[0033]

The cell can be any cell which can trigger the RNAi phenomenon by siRNAs, including cells derived from insects, worms, plants, mammals, and the like, preferably mammalian cells. Examples of the cells derived from plants include those derived from tomatoes, *nicotiana*, *Arabidopsis thaliana*, and rice plants. Examples of cells derived from mammals include those derived from mice, hamsters, and humans. Further, examples of suitable cultured cells include HeLa cells, NIH/3T3 cells, COS-7 cells, and 293 cells.

[0034]

A method for introducing the double-stranded RNA molecule of the present invention into the cell is not particularly limited and may be any method which can introduce the double-stranded nucleic acid molecule into the cell. As for the method of the present invention, a particularly suitable method for introducing the double-stranded RNA molecule into the cell is a transfection method using liposomes, preferably cationic liposomes, which can be easily carried out using a commercial transfection reagent such as Lipofectamine 2000 transfection reagent (Invitrogen), Oligofectamine transfection reagent (Invitrogen), jetSI transfection reagent (Polyplus-transfection), and TransMessenger (Qiagen).

[0035]

Alternatively, the suppression of the expression of a target gene utilizing the double-stranded RNA molecule of the present invention can be carried out by introducing into the cell of interest a vector which expresses the double-stranded RNA molecule of the present invention in a cell. In this method, either two types of vectors which can individually express the sense strand and antisense strand of the double-stranded RNA molecule of the present invention, or one vector which contains both of a DNA encoding the sense strand of the double-stranded RNA molecule of the present invention and a DNA encoding its antisense strand can be used. Thus, according to another embodiment of the present invention, there is provided a method for suppressing the expression of a target gene in a cell, comprising a step of introducing a combination of a vector containing a DNA encoding the sense strand of the double-stranded RNA molecule of the present invention and a vector containing a DNA encoding the antisense strand of said RNA molecule, or a vector comprising both of a DNA encoding the sense strand of the double-stranded RNA molecule of the present invention and a DNA encoding the antisense strand of said RNA molecule, into the cell.

[0036]

The abovementioned vector can be any one which is capable of expressing one or both of the strands of the double-stranded RNA molecule in a cell. Accordingly, the abovementioned vector contains DNA(s) encoding the strand(s) of the double-stranded RNA molecule

such that the DNA(s) can be transcribed in the cell. Such vector can be easily constructed by those skilled in the art; for example, elements such as promoters and terminators can be ligated in a functional form, if necessary. Any promoter which can function in the 5 cell of interest can be used; for example, either constitutive promoters or inducible promoters can be used. Further, the same promoter as that controlling the expression of the target gene can be used; thereby, the double-stranded RNA molecule of the present invention to decompose the transcription product of the target gene 10 can be produced at the same time when said transcription product is produced. The introduction of the constructed vector into the cell of interest can be appropriately carried out by those skilled in the art by a method known in the art.

[0037]

15 In particular, it is preferable to use a single vector capable of expressing both strands of the double-stranded RNA molecule of the present invention. Such a vector can be one that expresses the two strands of the double-stranded RNA molecule separately or one that expresses the double-stranded RNA molecule as a hairpin double-stranded RNA in which the two strands are linked by a linker sequence. 20 A vector that expresses the double-stranded RNA molecule of the present invention as a hairpin double-stranded RNA can be appropriately constructed by those skilled in the art; for example, it can be constructed according to the descriptions in literature (Bass, 25 B.L., Cell 101, 235-238, 2000; Tavernarakis, N. et al., Nat. Genet. 24, 180-183, 2000; Malagon, F. et al., Mol. Gen. Genet. 259, 639-644, 1998; Parrish, S. et al., Mol. Cell 6, 1077-1087, 2000).

[0038]

30 The double-stranded RNA molecule of the present invention and the method for suppressing the gene expression utilizing said RNA molecule can target a variety of genes; for example, a gene for which an analysis of its function in a cell is desired can be targeted. Further, by targeting cancer genes, virus genes and the like and 35 suppressing the expression of these genes, their functions can be elucidated, and furthermore by suppressing the expression of these genes in cells existing in the body, treatment of diseases and

disorders can be enabled.

[EXAMPLE]

[0039]

5 Example 1: Suppression of the expression of Photinus luciferase gene by various siRNAs in HeLa cells

Conventional siRNAs and siRNAs each carrying introduced mismatches with its antisense strand in various sites of its sense strand, against the Photinus luciferase gene, were designed to examine their effect on the suppression of the expression of the 10 Photinus luciferase gene.

[0040]

The nucleotide sequences of the various siRNAs thus designed are shown in Table 1 below. In Table 1, for each siRNA, the sense strand and antisense strand are aligned on the top row and the 15 bottom row, respectively, and nucleotides complementary to each other are shown with asterisks "*" between the strands. Further, as for the name of each siRNA, "La2" and "La21" represent the target sequences in the Photinus luciferase gene; according to the numbering system in the expression plasmid pGL3-control (Promega) 20 used for the introduction of said gene into the cell, "La2" targets the nucleotides at position 282-300 and "La21" targets the nucleotides at position 340-358. Further, "conv." represents an siRNA which is designed based on the conventional design standard and thus contains no mismatch.

25 [0041]

Table 1: siRNAs designed for *Photinus luciferase* gene

[0042]

The abovementioned paired oligoribonucleotides were synthesized and 20 μ M each of them were each mixed in an annealing buffer (30 mM HEPES pH 7.0, 100 mM potassium acetate, and 10 mM magnesium acetate), heat-denatured at 90°C for 3 minutes, and then annealed at 37°C for 24 hours. In this way, the individual siRNAs were obtained.

[0043]

HeLa cells were grown at 37°C in Dulbecco's modified Eagle's medium (Sigma) supplemented with 10% fetal bovine serum (Life Technologies), 100 U/ml penicillin (Life Technologies) and 100 μ g/ml streptomycin (Life Technologies) in a 5% CO₂ atmosphere.

[0044]

The day before transfection, the HeLa cells grown were trypsinized, diluted with the fresh medium without antibiotics and seeded into 24-well culture plates (appropriately 0.5×10^5 cell/well in 0.5 ml of the culture medium). Next, the culture medium was replaced with 0.5 ml of OPTI-MEMI (Life technologies), and to each well, 0.25 μ g of pGL3-control plasmid (Promega) to express Photinus luciferase, 0.05 μ g of phRL-TK plasmid (Promega) to express Renilla luciferase as a control, and 0.24 μ g of individual siRNA were applied. Cotransfection of the two kinds of reporter plasmids and the individual siRNA was carried out using a Lipofectamine 2000 transfection reagent (Invistrogen).

[0045]

Then, the cells were incubated at 37°C for 4 hours, and after adding 0.5 ml of the fresh culture medium without antibiotics, further incubated at 37°C. Cell lysate was prepared 24 hours after transfection and subjected to luciferase expression assay using Dual-Luciferase Reporter Assay System (Promega).

[0046]

Fig. 1 shows the results of the dual luciferase assay. In Fig. 1, ratios of target (Photinus) luciferase activity to control (Renilla) luciferase activity when individual siRNAs were used are shown. The ratios of these two kinds of luciferase activities are normalized to the ratio obtained for a control sample using a double-stranded RNA

(Mock, Qiagen) which triggers no gene expression suppression, setting the ratio to be 1.0. Data are averages of at least four independent experiments and error bars on the graph represent standard errors.

5 [0047]

Fig. 1a shows that La2-conv. exhibited gene expression suppression as strongly as about 98% while La21-conv. exhibited gene expression suppression as moderately as about 50%. This difference in the gene expression-suppressing effect between La2-
10 conv. and La21-conv. is thought to be due to the difference in the target sequence in the Photinus luciferase gene.

[0048]

Fig. 1b shows the gene expression-suppressing effect by various types of siRNAs which target La2 in the Photinus luciferase
15 gene. Comparisons La2-conv. versus La2-3'm1, La2-3'm2, La2-3'm3, and La2-3'm4 reveal that the introduction of 1-4 nucleotide mismatches in the 3'-end of the siRNA sense strand increased the target gene expression-suppressing effect by 2- to 3-fold. Among them, the siRNA carrying two nucleotide mismatches in the 3'-end of
20 the sense strand demonstrated the highest gene expression-suppressing effect. Further, the siRNA (La2-3'm2m12) carrying a mismatch in the nucleotide at position 12 from the 3'-end of the sense strand in addition to the two nucleotide mismatches at the 3'-end of the sense strand demonstrated a yet higher level of gene expression-suppressing effect. In contrast, the siRNA (La2-5'm2) carrying two
25 nucleotide mismatches at the 5'-end of the sense strand showed a lower gene expression-suppressing effect than the conventional siRNA (La2-conv.), which demonstrates that the introduction of mismatches at the 5'-end of the siRNA sense strand reduces the effect of the
30 siRNA on the gene expression suppression.

[0049]

Fig. 1c shows the gene expression-suppressing effect by various types of siRNAs which target La21 in the Photinus luciferase gene. Comparisons La21-conv. versus La21-3'm1, La21-3'm2, La21-
35 3'm3, and La21-3'm4 reveal that the introduction of 1-4 nucleotide mismatches in the 3'-end of the siRNA sense strand increased the

target gene expression-suppressing effect by 2- to 3-fold. Among them, the siRNA carrying two nucleotide mismatches in the 3'-end of the sense strand demonstrated the highest gene expression-suppressing effect. Further, the siRNA (La21-3'm2m12) carrying a 5 mismatch in the nucleotide at position 12 from the 3'-end of the sense strand in addition to the two nucleotide mismatches in the 3'-end of the sense strand demonstrated a yet higher level of gene expression-suppressing effect. These results agree with the results obtained by using various siRNAs targeting La2 as above; therefore, it is 10 understood that the augmentation of the gene expression-suppressing effect by the introduction of mismatches in the 3'-end of the siRNA sense strand as well as the introduction of a mismatch in the nucleotide at position 12 from the 3'-end is not controlled by the position of the target sequence in the target gene, the nucleotide 15 sequence of the target sequence, the gene expression-suppressing efficiency by conventional siRNAs without mismatches designed against the target sequence, or the like.

[0050]

20 Example 2: Suppression of the expression of Lamin A/C gene and Dnmt1 gene in HeLa cells by various siRNAs

As to the endogenous Lamin A/C gene and Dnmt1 gene capable of being expressed in HeLa cells, conventional siRNAs and siRNAs each carrying introduced mismatches with its antisense strand in various sites of its sense strand, directed against these genes, were 25 designed to examine their effect on the suppression of the expression of the abovementioned genes.

[0051]

The nucleotide sequences of the various siRNAs thus designed are shown in Table 2 below. In Table 2, for each siRNA, the sense 30 strand and antisense strand are aligned on the top row and the bottom row, respectively, and nucleotides complementary to each other are shown with asterisks "*" between the strands. Further, as for the name of each siRNA, "Lam" and "Dn1" represent the genes to be targeted, namely the Lamin A/C gene and Dnmt1 gene. According 35 to the numbering system in which the translation initiation codon "A" in the mRNA sequence of each gene is set to be 1, "Lam" targets the

nucleotides at position 829-851 in mRNA from the Lamin A/C gene, "Dn1(#1)" targets the nucleotides at position 70-89 in mRNA from the Dnmt1 gene, and "Dn1(#2)" targets the nucleotides at position 185-203 in mRNA from the Dnmt1 gene. Further, "Nat.Lam" is an siRNA which targets the Lamin A/C gene and its target sequence is described in literature (Elbrashir, S.M. et al., Nature 411; 494-498, 2001). Further, "conv." represents an siRNA which is designed based on the conventional design standard and thus contains no mismatch.

[0052]

Table 2: siRNAs designed for Lamin A/C gene and Dnmt1 gene

[0053]

The abovementioned paired oligoribonucleotides were synthesized and 20 μ M each of them were each mixed in an annealing buffer (30 mM HEPES pH 7.0, 100 mM potassium acetate, and 10 mM magnesium acetate), heat-denatured at 90°C for 3 minutes, and then annealed at 37°C for 24 hours. In this way, the individual siRNAs were obtained.

[0054]

HeLa cells were grown at 37°C in Dulbecco's modified Eagle's medium (Sigma) supplemented with 10% fetal bovine serum (Life Technologies), 100 U/ml penicillin (Life Technologies) and 100 μ g/ml streptomycin (Life Technologies) in a 5% CO₂ atmosphere.

[0055]

Transfection of each siRNA (100 nM) into HeLa cells was carried out using a jetSI transfection reagent (Polyplus-transfection).

[0056]

Total RNA was extracted 48 hours after transfection and subjected to cDNA synthesis by reverse transcriptase. The level of expression of the target gene was measured by real-time PCR using this cDNA as a template. A series of these expression level measurements were carried out using a SYBER Green PCR kit (Molecular Probe).

[0057]

Fig. 2 shows the effect of the various siRNAs on suppressing the expression of the endogenous genes in HeLa cells. In Fig. 2, ratios of the expression level of target genes (Lamin A/C or Dnmt1 gene) to that of the control gene (G3PDH gene) are shown. These expression level ratios are normalized to the ratio obtained for a control sample using a double-stranded RNA (Mock, Qiagen) which triggers no gene expression suppression, setting the ratio to be 1.0. Data are averages of at least four independent experiments and error bars on the graph represent standard errors.

[0058]

As shown in Fig. 2a and Fig. 2b, it is evident that the siRNAs carrying a mismatch in the nucleotide at position 12 from the 3'-end of the sense strand in addition to two nucleotide mismatches in the 3'-

end of the sense strand demonstrated a higher level of gene expression-suppressing effect as compared to the conventional siRNAs.
[BRIEF DESCRIPTION OF THE DRAWINGS]

[0059]

5 [Fig. 1] Fig. 1 shows graphs illustrating the results of the dual luciferase assay showing the effect of various types of siRNAs on suppressing the expression of the Photinus luciferase gene in HeLa cells.

10 [Fig. 2] Fig. 2 shows graphs illustrating the effect of various types of siRNAs on suppressing the expression of endogenous genes in HeLa cells.

;

;

[SEQUENCE LISTING]

SEQUENCE LISTING

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[Document Name] ABSTRACT

[Abstract]

[Problem to be solved] Provision of a double-stranded RNA molecule improved to control the gene expression suppressing effect of an

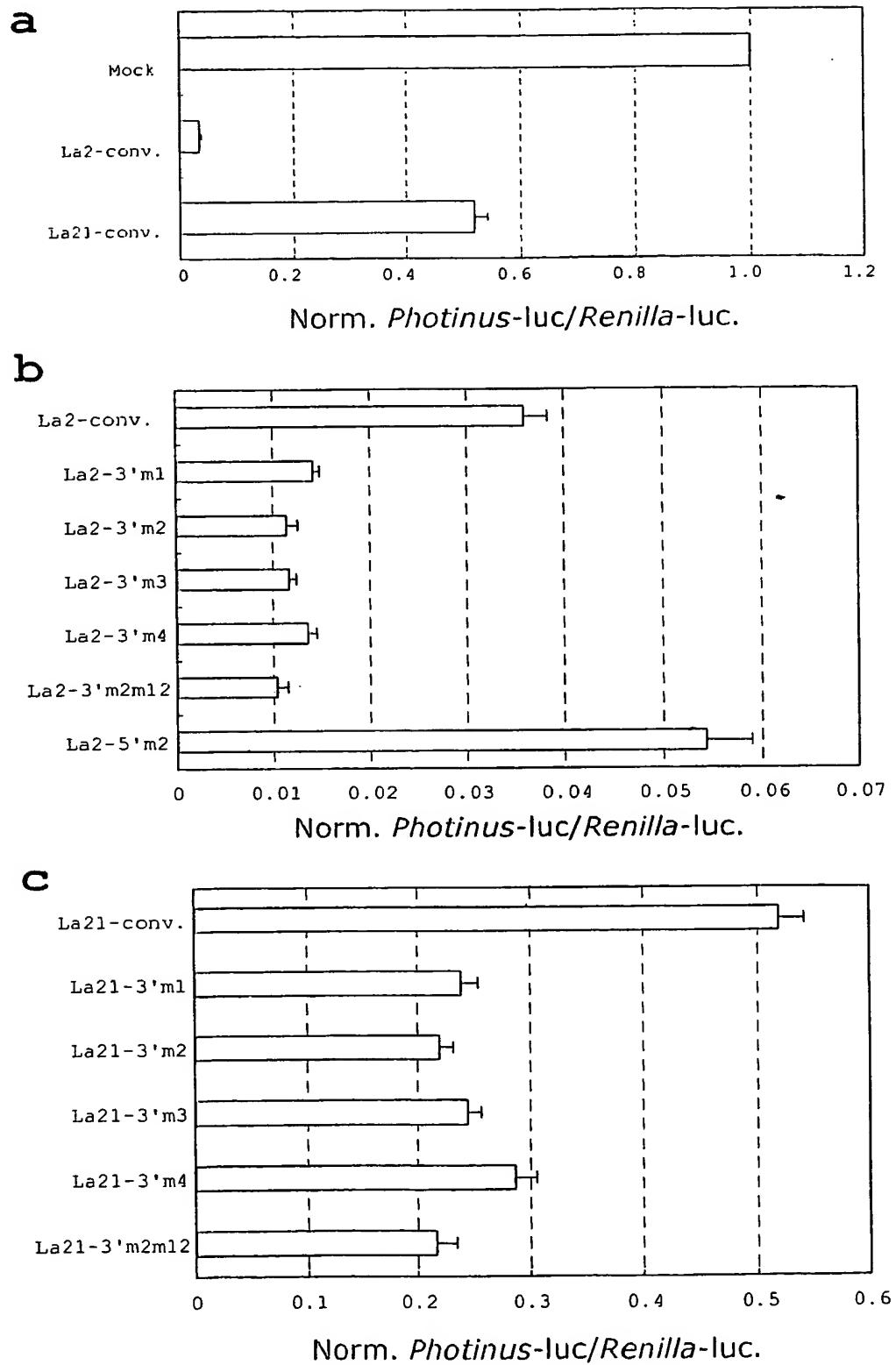
5 siRNA.

[Solution] A double-stranded RNA molecule capable of suppressing the expression of a target gene in a cell by RNAi, which is designed such that one or more nucleotides in order from the 3'-end or 5'-end of the sense strand of double-stranded part in said RNA molecule are 10 not complementary to the antisense strand, wherein the sense strand of the double-stranded part has adequate number of nucleotides which are complementary to the antisense strand for enabling the hybridization of both strands in said cell.

[Selected figure] none

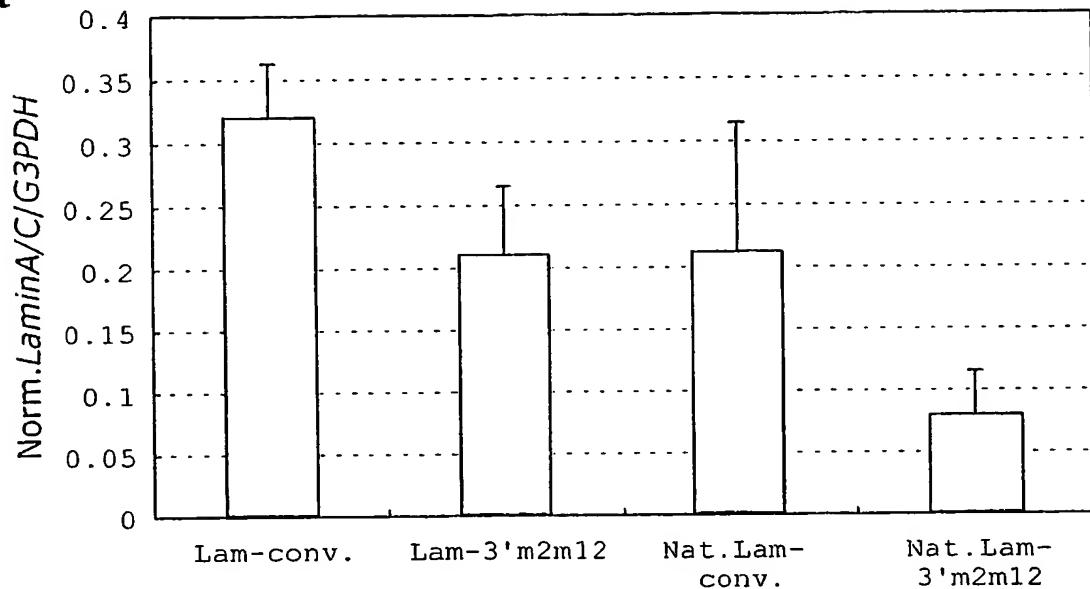
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[Document Name] FIGURE
[Figure 1]



[Figure 2]

a



b

